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(54) Apparatus for drawing optical fibers.

(57) An optical waveguide fiber drawing system is disclosed having means (24) for cooling the hot fiber (16) prior to the time that the fiber (16') enters a coating apparatus (20). The cooling means (24) comprises an elongated tube (30', 76) through which the fiber (16) passes. Cool dry gas (92) is flowed from an annular slot (42') surrounding the fiber (16), preferably so that it has a flow component directed radially inwardly toward the fiber (16) and a flow component which is directed longitudinally toward the opposite end of the tube (79).

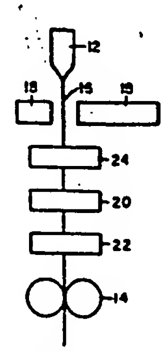

Fig. 1

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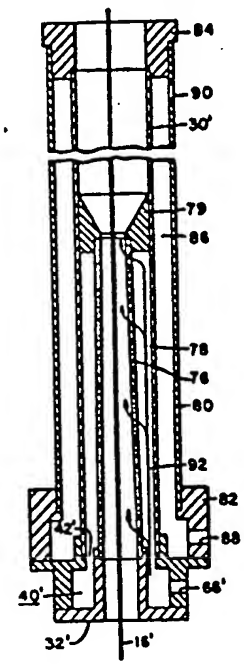


Fig. 3

APPARATUS FOR DRAWING OPTICAL FIBERS

Glass optical waveguide fibers are remarkably strong as they are drawn, but their strength is greatly affected by physical handling. They must therefore be coated with a protective material before they come in contact with the fiber drawing tractors. For a number of reasons including improved diameter control and cleanliness, the tractors should be as close as possible to the draw furnace. At a fixed distance from the furnace, the fiber becomes hotter as draw rate increases. Thus, to cool a fiber by natural cooling, longer distances are required for higher draw speeds. For example, to cool a 125 μm diameter fiber from 1780°C to a temperature needed to apply a cellulose acetate lacquer solution with acetone, approximately 0.8 m of cooling distance is required for a draw speed of 0.5 m/sec. A distance of 1.2 m is required to cool that fiber to 50°C at a draw speed of 0.75 m/sec., and 8 m is required if the draw speed is 5 m/sec.

The economical production of large quantities of optical waveguide fibers will undoubtedly require fiber drawing speeds greater than 1 m/sec. If no fiber cooling means is employed and if the distance between the furnace and the coating apparatus is not sufficiently long, there may be insufficient time at such higher drawing speeds for the fibers to cool by natural processes to temperatures which are compatible with application techniques employing presently developed waveguide coating materials. When the temperature of the fiber is too high, the coating may become too thin or discontinuous. If the coating is applied from a 100% solids solution, the hot fiber can cause the coating material to set up in the coating apparatus around the fiber, thus preventing any further coating material from being applied to the fiber.

The optical waveguide fiber coating system disclosed in U.S. Patent No. 4,208,200 employs means for cooling the hot fiber prior to its entering the coating apparatus. The cooling means comprises an elongate, liquid filled container through which the fiber passes. The bottom of the container is provided with a felt wiping die which seals the container and removes excess liquid from the fiber. In a system employing this type of fiber cooling device the fiber can become so hot that it boils the liquid at high draw rates. This causes turbulence which can move the fiber laterally so that it is displaced from its proper position in the diameter measuring device. Also, the wiping means physically contacts the fiber, a factor which might adversely affect fiber strength.

It is therefore an object of the present invention to provide an apparatus capable of coating glass optical fibers that are drawn at relatively high drawing speeds.

According to the present invention there is provided an apparatus for drawing optical fibers comprising: a source of softened or molten glass from which a fiber is drawn; means for cooling said fiber; and means for applying a protective coating to said fiber; characterized in that said cooling means comprises an elongate tube surrounding said fiber; a source of coolant gas; means for cooling said coolant gas; and means for flowing said cooled coolant gas into said tube.

According to a further embodiment of the present invention a fiber drawing apparatus comprises a source of softened or molten glass from which a fiber is drawn, means for cooling the fiber, and means for applying a protective coating to the fiber. The means for cooling is characterized in that it comprises an elongate tube surrounding said fiber, a source of cooled coolant gas, and means surrounding said fiber at one end of the tube for flowing the cooled coolant gas so that it has a flow component

which is directed radially inwardly toward the fiber and a flow component which is directed longitudinally toward the opposite end of the tube.

Preferably, the coolant gas is helium.

In the accompanying drawings:

Figure 1 is a schematic illustration in block diagram form of an optical fiber drawing system;

Figure 2 is a cross-sectional view of a fiber cooling apparatus of the present invention; and

Figure 3 is a cross-sectional view illustrating an alternative embodiment of the fiber cooling apparatus of the present invention.

It is to be noted that the drawings are illustrative and symbolic of the present invention and that there is no intention to indicate the scale or relative proportions of the elements shown therein.

The conventional fiber drawing system shown in Figure 1 comprises a mass of glass 12 at least the tip of which is molten, and a pair of tractors 14 for drawing a fiber 16 from the molten glass. The output of an optical micrometer 18 is coupled to a control system which regulates the speed of the tractors 14 to control the diameter of the fiber. The fiber 16 passes through a coater 20 which applies to protective material thereto, and thereafter, it may pass through a dryer 22. At high draw speeds it is necessary to employ means 24 to cool the fiber to a temperature which does not detrimentally affect the coating material applied at coater 20.

A preferred embodiment of the improved fiber cooling means of the present invention is illustrated in Figure 2. Fiber 16 is drawn through a cylindrical coolant tube 30 which may be formed, for example, of stainless steel, glass, copper or aluminium. Tube 30 is provided with a lower end cap 32 for supplying thereto a dry, coolant gas such as helium, carbon dioxide or the like

and with an upper end cap 34 for exhausting the helium or other coolant gas. End caps 32 and 34 are provided with inwardly projecting flanges 36 and 38, respectively, against which the ends of tube 30 abut. End cap 32 includes an annular manifold 40 which is connected to an annular slot 42. End cap 34 is provided with an annular manifold 46 which is connected to an annular slot 48. The central region of tube 30 between end caps 32 and 34 may be surrounded by a layer 50 of insulating material. The end caps may be provided with seats which receive iris diaphragms 54, and 56, respectively.

A source 60 of helium is connected by way of a heat exchanger 62 to an inlet orifice 66 of manifold 40. Heat exchanger 62 comprises an insulated reservoir containing a liquified gas such as liquid nitrogen, liquid argon, liquid helium or the like. Liquid nitrogen is preferred since it is relatively inexpensive. The helium from source 60 flows through a coil 68 which is submerged in the liquified gas. As the cooled helium emanates from annular slot 42, it flows toward fiber 16, and its buoyancy causes it to flow upwardly through tube 30. It is exhausted by way of slot 48, manifold 46 and exhaust orifice 72.

The iris diaphragms, which are commercially available, can be initially adjusted to provide a relatively large opening until the drawing process achieves steady state conditions. They can then be adjusted to provide relatively narrow openings to restrict the flow of helium from tube 30 in order to reduce the consumption of that gas. The iris diaphragms may be omitted, especially if the diameter of tube 30 is sufficiently small that a minimal amount of helium is required to fill that tube. Also, the top end cap is not essential although it is a useful element if the helium is to be recovered. The helium flowing through tube 30 may be exhausted directly from the open

end thereof.

The following specific example illustrates the advantages of the apparatus of the prevent invention. The apparatus of Figure 2 was employed except that the iris diaphragms and the top end cap 34 were not employed. The length of tube 30 was 1.2 m, and the inside diameter thereof was 12.7 mm. The opening in the bottom of end cap 32 through which fiber 16 extends was 8.7 mm. The outside diameter of insulating tube 50 was 76.2 mm.

The heat exchanger 62 was constructed by forming into a 101.6 mm diameter coil a section of 4.8 mm OD copper tubing having length of 2.67 m. The coil was submerged in a dewar of liquid nitrogen. This apparatus was capable of cooling helium gas flowing therethrough to liquid nitrogen temperature.

The top of cooler 30 was located 0.81 m below the bottom of the fiber draw furnace. The coater was situated 0.3 m below the bottom of cooling means 24. A pure fused silica fiber having a diameter of 125 μm was drawn from the furnace at a temperature about 2250°C. Coater 20 applied to the fiber a coating of DeSoto 950x037 UV curable acrylate. The fiber draw rate was varied from 1 to 5 m/sec. The fiber temperature at the top of the cooler and the minimum helium flow rate required to provide a constant coating thickness are set forth in Table 1.

Table 1

Draw Speed (m/sec)	Fiber Temp.. at Top of Tube 30 (°C)	He Flow Required for Constant Coating Thickness (ℓ/min)
1	160	2.7
2	355	5.3
3	465	10.5
4	540	20.4
5	585	39.9

It is noted that in order to achieve a constant coating thickness, the fiber temperature at the input of the coater must not exceed some predetermined value depending upon the particular coating material employed. For the DeSoto 950x037 UV curable coating, the maximum fiber temperature is about 40°C. While this type of coating material was being applied, a drawing apparatus employing a fiber cooler of the type shown in Figure 2 was capable of drawing fiber at the rate of 6.2 m/sec. without any decrease in coating thickness. The drawing rate was limited by the inherent limit of the drawing apparatus and not by the inability of the fiber cooler to cool the fiber while maintaining fiber stability.

However, in a simplified, broader embodiment the apparatus merely comprises means for flowing the coolant gas into the elongate tube, which may be accomplished, for example, by connecting to the elongate tube at any point of its longitudinal extension one or more tubes which direct a coolant gas inwardly toward the fiber.

In the embodiment shown in Figure 3, in which elements similar to those of Figure 2 are represented by primed reference numerals, the helium is diffused radially inwardly toward fiber 16' through a cylindrically-shaped, porous member 76 which may comprise a screen, porous metal tube, perforated metal tube or the like. The bottom end of tube 76 is supported by end cap 32' and the top end thereof is supported by a bracket 79 which is supported by tube 30'. A tubular housing 80, which is supported by brackets 82 and 84, forms a chamber 86 in which a liquified gas such as liquid nitrogen is disposed. This prevents heat from being transferred inwardly to the helium flowing in tube 30' from the ambient air. Chamber 86 is provided with an inlet orifice 88 and an exhaust orifice 90.

Cooled helium flows through inlet orifice 66', annular manifold 40' and annular slot 42' into a cylindrical chamber

78, which is formed between porous member 76 and tube 30'. As illustrated by multi-headed arrow 92, the helium diffuses through porous member 76 toward fiber 16'. Thus the tendency of the inflowing helium to vibrate fiber 16' is minimized.

Whereas porous member 76 is illustrated as being slightly tapered, the walls thereof may be parallel. A 320 mesh untapered cylindrical screen has been satisfactorily demonstrated.

CLAIMS:

1. An apparatus for drawing optical fibers comprising: a source of softened or molten glass from which a fiber is drawn; means for cooling said fiber; and means for applying a protective coating to said fiber; characterized in that said cooling means comprises an elongate tube surrounding said fiber; a source of coolant gas; means for cooling said coolant gas; and means for flowing said cooled coolant gas into said tube.

2. An apparatus in accordance with claim 1, wherein said means for flowing said coolant gas into said tube comprises means surrounding said fiber at one end of said tube for flowing said coolant gas such that it has a flow component which si directed radially inwardly toward said fiber and a flow component which is directed longitudinally toward the opposite end of said tube.

3. An apparatus in accordance with claim 1 or 2, wherein said means for directing coolant gas is situated at the end of said tube from which said fiber exits..

4. An apparatus in accordance with claim 3, wherein said elongate tube is vertically orientated and said means for directing coolant gas comprises an annular manifold co-axially disposed with respect to said tube and an annular slot connecting said manifold to the bottom end of said tube.

5. An apparatus in accordance with claim 4, further comprising means at the top end of said tube for exhausting the coolant gas flowing through said tube.

6. An apparatus in accordance with any one of claims 1 to 3, wherein said means for directing coolant gas comprises a cylindrically-shaped porous member surounding said fiber at one end of said tube, a chamber surrounding said porous member, and means for supplying said coolant gas to said chamber.

7. An apparatus in accordance with claim 6, wherein said elongate tube is vertically orientated, said cylindrically-shaped porous member being located at the bottom end of said tube.

8. An apparatus according to any one of the preceding claims, wherein said coolant gas is helium.

9. An apparatus in accordance with any one of the preceding claims further comprising an iris diaphragm at that end of said tube into which said fiber enters, or at both ends of said tube.

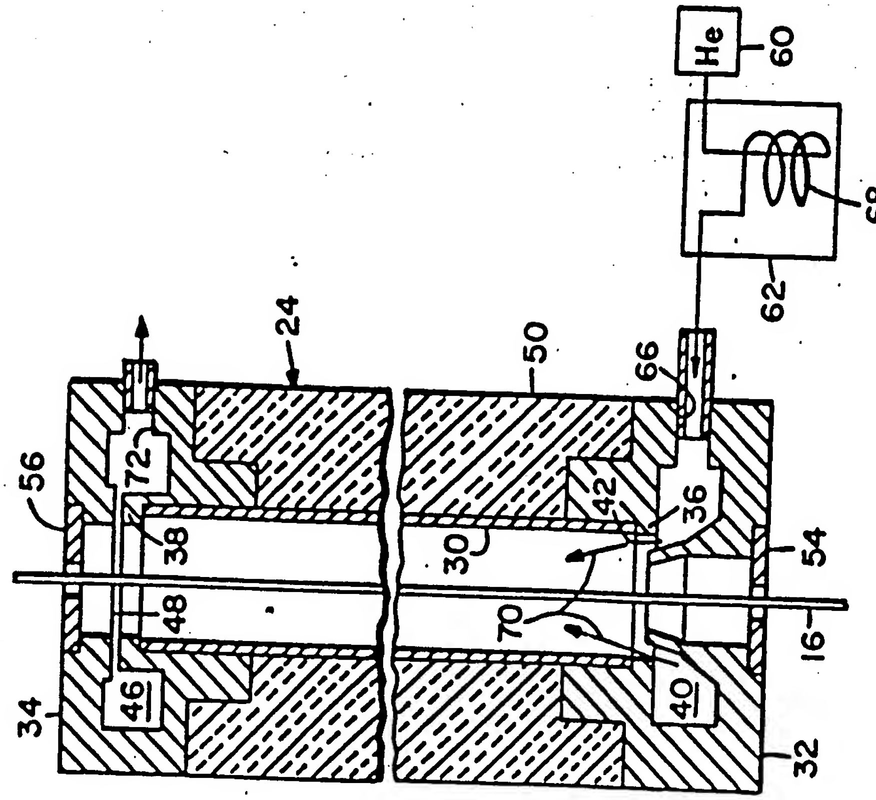
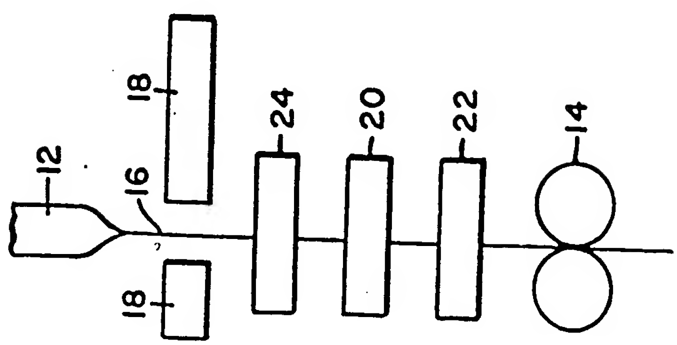

24
50
56
72
34
46
48
38
30
70
42
36
40
66
54
16
32
He
60
68
62

Fig. 2


12
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18
24
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14

Fig. 1

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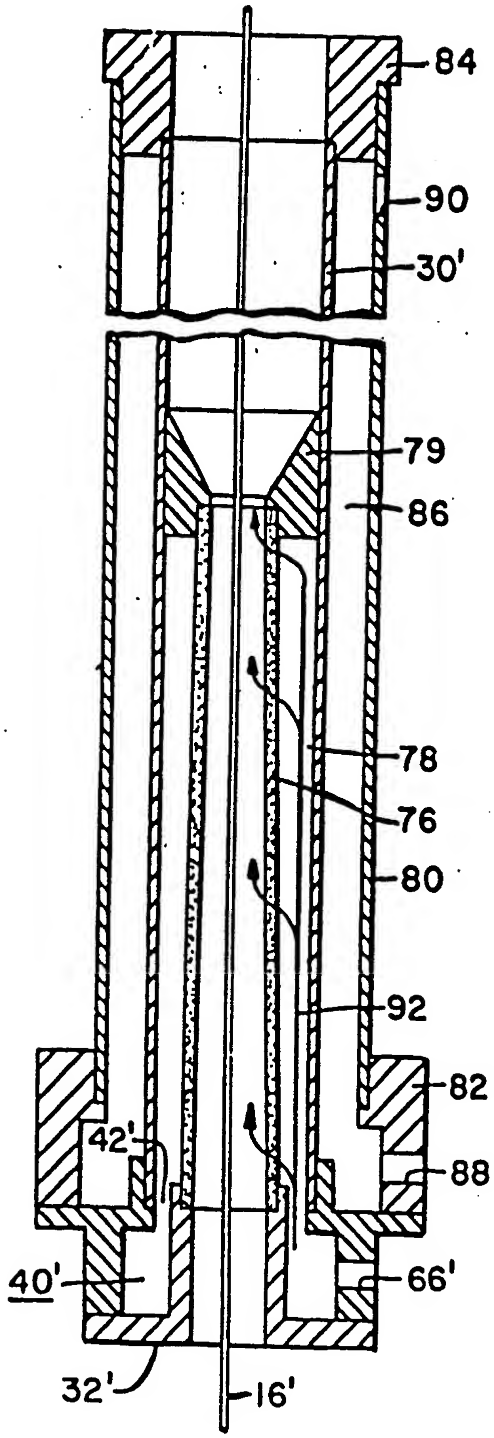

Fig. 3

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EUROPEAN SEARCH REPORT

0079186
Application number

EP 82 30 5789

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
X	GB-A-2 044 751 (N.V. PHILIPS GLOEILAMPENFABRIEKEN) * Claims 1, 2, 5; page 1, lines 122-128, page 3, lines 74-98 *	1	C 03 B 37/025 C 03 B 37/02 C 03 C 25/02
A	JOURNAL OF APPLIED PHYSICS, vol. 50, no. 10, October 1979, American Institute of Physics, USA U.C. PAEK et al. "Forced convective cooling of optical fibers in high-spee coating", pages 6144-6148 * Page 6146, column 2; figure 2b *	1,2	
D,A	US-A-4 208 200 (S.A. CLAYPOOLE et al.) * Claim 1 *		

TECHNICAL FIELDS SEARCHED (Int. Cl. 3)

C 03 B 37/00
C 03 C 25/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	25-01-1983	STROUD J.G.

CATEGORY OF CITED DOCUMENTS

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